

## UNPUBLISHED PRELIMINARY DATA

Consummatory Behavior in Rats Maintained A-Periodically<sup>1</sup>  
Robert C. Bolles  
Hollins College

## Abstract

96 rats were maintained and tested on irregular feeding or drinking schedules so that food and water consumption could be assessed as a function of the time of day of testing, hours deprivation, and deprivation experience, without the usual experimental confounding among these variables. In the first experiment hungry and thirsty animals were tested in their homecages. Drinking was found to increase with deprivation time at least up to 42 hrs., whereas eating changed very little between 7 and 42 hrs. deprivation. In the second experiment hungry animals, tested in a bar press situation, showed maximum intake at 24 hrs. to 32 hrs. deprivation.

*2 Copies*

FACILITY FORM 602	N66 85211	
	(ACCESSION NUMBER)	(THRU)
	15	None
	(PAGES)	(CODE)
	CR-60334	
	(NASA CR OR TMX OR AD NUMBER)	(CATEGORY)

~~AVAILABLE TO NASA OFFICE AND FIELD CENTERS ONLY~~

Consummatory Behavior in Rats Maintained A-Periodically.  
Robert C. Bolles  
Hollins College

Although an animal's consumption of food or water is often accepted as a direct measure of its hunger or thirst motivation, it is more constructive to think of amount consumed as a response measure which depends in part upon the animal's motivation, but also in part upon the strength of the consummatory habit in the test situation. The strength of the eating and drinking habits presumably depend upon 1) the animal's experience in the test situation, i.e., the number of "trials" it has had there, and 2) generalization decrements arising from the dissimilarity of stimuli present in the test situation from those present in the situation where and when the animal ordinarily eats or drinks.

Although all of these effects have been studied, demonstrations of any one effect - deprivation time, test experience, time of day of testing - are generally confounded by other concomitant effects. For example, some investigators (Bare, 1959; Bousfield & Elliott, 1934; Kessen, Kimble & Hillman, 1960; Lawrence & Mason, 1955a; Mandler, 1957) have studied the effect of different hours of food or water deprivation with tests coming at different times of day. In these cases it is not possible to know what part of the results can be attributed to variation in deprivation and what part to the temporal conditions of the tests. In some cases (Lawrence & Mason, Kessen et al.) attempts have been made to separate these factors, and the results do show that there is a marked increase in intake when the time of testing fell at an accustomed consummatory hour. Hence, it is suggested that stimuli arising from the time of day may play an important part in the determination of consummatory behavior. But the relative size of the effect is not certain.

Others (Horenstein, 1951; Miller, 1956; Stellar & Hill, 1952) have studied the effect of food or water deprivation time with the tests always run at the same time of day, but in these cases the deprivation effect may be confounded with the animal's experience in the new eating or drinking situation. Finally, there have been studies (Ghent, 1951, 1957; Lawrence & Mason, 1955b) of the acquisition of eating and drinking behavior in a novel test situation, but once again the magnitude of the effect is uncertain because of the fact that there may have been cumulative deprivation effects which were confounded with experience in the test situation.

Experiment 1

The present investigation was designed to minimize

~~ALL INFORMATION CONTAINED HEREIN IS UNCLASSIFIED~~  
~~DATE 11-11-81 BY 1045/1046/1047/1048/1049/1050/1051/1052/1053/1054/1055/1056/1057/1058/1059/1060/1061/1062/1063/1064/1065/1066/1067/1068/1069/1070/1071/1072/1073/1074/1075/1076/1077/1078/1079/1080/1081/1082/1083/1084/1085/1086/1087/1088/1089/1090/1091/1092/1093/1094/1095/1096/1097/1098/1099/1100/1101/1102/1103/1104/1105/1106/1107/1108/1109/1110/1111/1112/1113/1114/1115/1116/1117/1118/1119/1120/1121/1122/1123/1124/1125/1126/1127/1128/1129/1130/1131/1132/1133/1134/1135/1136/1137/1138/1139/1140/1141/1142/1143/1144/1145/1146/1147/1148/1149/1150/1151/1152/1153/1154/1155/1156/1157/1158/1159/1160/1161/1162/1163/1164/1165/1166/1167/1168/1169/1170/1171/1172/1173/1174/1175/1176/1177/1178/1179/1180/1181/1182/1183/1184/1185/1186/1187/1188/1189/1190/1191/1192/1193/1194/1195/1196/1197/1198/1199/1200/1201/1202/1203/1204/1205/1206/1207/1208/1209/1210/1211/1212/1213/1214/1215/1216/1217/1218/1219/1220/1221/1222/1223/1224/1225/1226/1227/1228/1229/1230/1231/1232/1233/1234/1235/1236/1237/1238/1239/1240/1241/1242/1243/1244/1245/1246/1247/1248/1249/1250/1251/1252/1253/1254/1255/1256/1257/1258/1259/1260/1261/1262/1263/1264/1265/1266/1267/1268/1269/1270/1271/1272/1273/1274/1275/1276/1277/1278/1279/1280/1281/1282/1283/1284/1285/1286/1287/1288/1289/1290/1291/1292/1293/1294/1295/1296/1297/1298/1299/1300/1301/1302/1303/1304/1305/1306/1307/1308/1309/1310/1311/1312/1313/1314/1315/1316/1317/1318/1319/1320/1321/1322/1323/1324/1325/1326/1327/1328/1329/1330/1331/1332/1333/1334/1335/1336/1337/1338/1339/1340/1341/1342/1343/1344/1345/1346/1347/1348/1349/1350/1351/1352/1353/1354/1355/1356/1357/1358/1359/1360/1361/1362/1363/1364/1365/1366/1367/1368/1369/1370/1371/1372/1373/1374/1375/1376/1377/1378/1379/1380/1381/1382/1383/1384/1385/1386/1387/1388/1389/1390/1391/1392/1393/1394/1395/1396/1397/1398/1399/1400/1401/1402/1403/1404/1405/1406/1407/1408/1409/1410/1411/1412/1413/1414/1415/1416/1417/1418/1419/1420/1421/1422/1423/1424/1425/1426/1427/1428/1429/1430/1431/1432/1433/1434/1435/1436/1437/1438/1439/1440/1441/1442/1443/1444/1445/1446/1447/1448/1449/1450/1451/1452/1453/1454/1455/1456/1457/1458/1459/1460/1461/1462/1463/1464/1465/1466/1467/1468/1469/1470/1471/1472/1473/1474/1475/1476/1477/1478/1479/1480/1481/1482/1483/1484/1485/1486/1487/1488/1489/1490/1491/1492/1493/1494/1495/1496/1497/1498/1499/1500/1501/1502/1503/1504/1505/1506/1507/1508/1509/1510/1511/1512/1513/1514/1515/1516/1517/1518/1519/1520/1521/1522/1523/1524/1525/1526/1527/1528/1529/1530/1531/1532/1533/1534/1535/1536/1537/1538/1539/1540/1541/1542/1543/1544/1545/1546/1547/1548/1549/1550/1551/1552/1553/1554/1555/1556/1557/1558/1559/1560/1561/1562/1563/1564/1565/1566/1567/1568/1569/1570/1571/1572/1573/1574/1575/1576/1577/1578/1579/1580/1581/1582/1583/1584/1585/1586/1587/1588/1589/1590/1591/1592/1593/1594/1595/1596/1597/1598/1599/1600/1601/1602/1603/1604/1605/1606/1607/1608/1609/1610/1611/1612/1613/1614/1615/1616/1617/1618/1619/1620/1621/1622/1623/1624/1625/1626/1627/1628/1629/1630/1631/1632/1633/1634/1635/1636/1637/1638/1639/1640/1641/1642/1643/1644/1645/1646/1647/1648/1649/1650/1651/1652/1653/1654/1655/1656/1657/1658/1659/1660/1661/1662/1663/1664/1665/1666/1667/1668/1669/1670/1671/1672/1673/1674/1675/1676/1677/1678/1679/1680/1681/1682/1683/1684/1685/1686/1687/1688/1689/1690/1691/1692/1693/1694/1695/1696/1697/1698/1699/1700/1701/1702/1703/1704/1705/1706/1707/1708/1709/1710/1711/1712/1713/1714/1715/1716/1717/1718/1719/1720/1721/1722/1723/1724/1725/1726/1727/1728/1729/1730/1731/1732/1733/1734/1735/1736/1737/1738/1739/1740/1741/1742/1743/1744/1745/1746/1747/1748/1749/1750/1751/1752/1753/1754/1755/1756/1757/1758/1759/1760/1761/1762/1763/1764/1765/1766/1767/1768/1769/1770/1771/1772/1773/1774/1775/1776/1777/1778/1779/1780/1781/1782/1783/1784/1785/1786/1787/1788/1789/1790/1791/1792/1793/1794/1795/1796/1797/1798/1799/1800/1801/1802/1803/1804/1805/1806/1807/1808/1809/1810/1811/1812/1813/1814/1815/1816/1817/1818/1819/1820/1821/1822/1823/1824/1825/1826/1827/1828/1829/1830/1831/1832/1833/1834/1835/1836/1837/1838/1839/1840/1841/1842/1843/1844/1845/1846/1847/1848/1849/1850/1851/1852/1853/1854/1855/1856/1857/1858/1859/1860/1861/1862/1863/1864/1865/1866/1867/1868/1869/1870/1871/1872/1873/1874/1875/1876/1877/1878/1879/1880/1881/1882/1883/1884/1885/1886/1887/1888/1889/1890/1891/1892/1893/1894/1895/1896/1897/1898/1899/1900/1901/1902/1903/1904/1905/1906/1907/1908/1909/1910/1911/1912/1913/1914/1915/1916/1917/1918/1919/1920/1921/1922/1923/1924/1925/1926/1927/1928/1929/1930/1931/1932/1933/1934/1935/1936/1937/1938/1939/1940/1941/1942/1943/1944/1945/1946/1947/1948/1949/1950/1951/1952/1953/1954/1955/1956/1957/1958/1959/1960/1961/1962/1963/1964/1965/1966/1967/1968/1969/1970/1971/1972/1973/1974/1975/1976/1977/1978/1979/1980/1981/1982/1983/1984/1985/1986/1987/1988/1989/1990/1991/1992/1993/1994/1995/1996/1997/1998/1999/2000/2001/2002/2003/2004/2005/2006/2007/2008/2009/2010/2011/2012/2013/2014/2015/2016/2017/2018/2019/2020/2021/2022/2023/2024/2025/2026/2027/2028/2029/2030/2031/2032/2033/2034/2035/2036/2037/2038/2039/2040/2041/2042/2043/2044/2045/2046/2047/2048/2049/2050/2051/2052/2053/2054/2055/2056/2057/2058/2059/2060/2061/2062/2063/2064/2065/2066/2067/2068/2069/2070/2071/2072/2073/2074/2075/2076/2077/2078/2079/2080/2081/2082/2083/2084/2085/2086/2087/2088/2089/2090/2091/2092/2093/2094/2095/2096/2097/2098/2099/2100/2101/2102/2103/2104/2105/2106/2107/2108/2109/2110/2111/2112/2113/2114/2115/2116/2117/2118/2119/2120/2121/2122/2123/2124/2125/2126/2127/2128/2129/2130/2131/2132/2133/2134/2135/2136/2137/2138/2139/2140/2141/2142/2143/2144/2145/2146/2147/2148/2149/2150/2151/2152/2153/2154/2155/2156/2157/2158/2159/2160/2161/2162/2163/2164/2165/2166/2167/2168/2169/2170/2171/2172/2173/2174/2175/2176/2177/2178/2179/2180/2181/2182/2183/2184/2185/2186/2187/2188/2189/2190/2191/2192/2193/2194/2195/2196/2197/2198/2199/2200/2201/2202/2203/2204/2205/2206/2207/2208/2209/2210/2211/2212/2213/2214/2215/2216/2217/2218/2219/2220/2221/2222/2223/2224/2225/2226/2227/2228/2229/2230/2231/2232/2233/2234/2235/2236/2237/2238/2239/2240/2241/2242/2243/2244/2245/2246/2247/2248/2249/2250/2251/2252/2253/2254/2255/2256/2257/2258/2259/2260/2261/2262/2263/2264/2265/2266/2267/2268/2269/2270/2271/2272/2273/2274/2275/2276/2277/2278/2279/2280/2281/2282/2283/2284/2285/2286/2287/2288/2289/2290/2291/2292/2293/2294/2295/2296/2297/2298/2299/2300/2301/2302/2303/2304/2305/2306/2307/2308/2309/2310/2311/2312/2313/2314/2315/2316/2317/2318/2319/2320/2321/2322/2323/2324/2325/2326/2327/2328/2329/2330/2331/2332/2333/2334/2335/2336/2337/2338/2339/2340/2341/2342/2343/2344/2345/2346/2347/2348/2349/2350/2351/2352/2353/2354/2355/2356/2357/2358/2359/2360/2361/2362/2363/2364/2365/2366/2367/2368/2369/2370/2371/2372/2373/2374/2375/2376/2377/2378/2379/2380/2381/2382/2383/2384/2385/2386/2387/2388/2389/2390/2391/2392/2393/2394/2395/2396/2397/2398/2399/2400/2401/2402/2403/2404/2405/2406/2407/2408/2409/2410/2411/2412/2413/2414/2415/2416/2417/2418/2419/2420/2421/2422/2423/2424/2425/2426/2427/2428/2429/2430/2431/2432/2433/2434/2435/2436/2437/2438/2439/2440/2441/2442/2443/2444/2445/2446/2447/2448/2449/2450/2451/2452/2453/2454/2455/2456/2457/2458/2459/2460/2461/2462/2463/2464/2465/2466/2467/2468/2469/2470/2471/2472/2473/2474/2475/2476/2477/2478/2479/2480/2481/2482/2483/2484/2485/2486/2487/2488/2489/2490/2491/2492/2493/2494/2495/2496/2497/2498/2499/2500/2501/2502/2503/2504/2505/2506/2507/2508/2509/2510/2511/2512/2513/2514/2515/2516/2517/2518/2519/2520/2521/2522/2523/2524/2525/2526/2527/2528/2529/2530/2531/2532/2533/2534/2535/2536/2537/2538/2539/2540/2541/2542/2543/2544/2545/2546/2547/2548/2549/2550/2551/2552/2553/2554/2555/2556/2557/2558/2559/2560/2561/2562/2563/2564/2565/2566/2567/2568/2569/2570/2571/2572/2573/2574/2575/2576/2577/2578/2579/2580/2581/2582/2583/2584/2585/2586/2587/2588/2589/2590/2591/2592/2593/2594/2595/2596/2597/2598/2599/2600/2601/2602/2603/2604/2605/2606/2607/2608/2609/2610/2611/2612/2613/2614/2615/2616/2617/2618/2619/2620/2621/2622/2623/2624/2625/2626/2627/2628/2629/2630/2631/2632/2633/2634/2635/2636/2637/2638/2639/2640/2641/2642/2643/2644/2645/2646/2647/2648/2649/2650/2651/2652/2653/2654/2655/2656/2657/2658/2659/2660/2661/2662/2663/2664/2665/2666/2667/2668/2669/2670/2671/2672/2673/2674/2675/2676/2677/2678/2679/2680/2681/2682/2683/2684/2685/2686/2687/2688/2689/2690/2691/2692/2693/2694/2695/2696/2697/2698/2699/2700/2701/2702/2703/2704/2705/2706/2707/2708/2709/2710/2711/2712/2713/2714/2715/2716/2717/2718/2719/2720/2721/2722/2723/2724/2725/2726/2727/2728/2729/2730/2731/2732/2733/2734/2735/2736/2737/2738/2739/2740/2741/2742/2743/2744/2745/2746/2747/2748/2749/2750/2751/2752/2753/2754/2755/2756/2757/2758/2759/2760/2761/2762/2763/2764/2765/2766/2767/2768/2769/2770/2771/2772/2773/2774/2775/2776/2777/2778/2779/2780/2781/2782/2783/2784/2785/2786/2787/2788/2789/2790/2791/2792/2793/2794/2795/2796/2797/2798/2799/2800/2801/2802/2803/2804/2805/2806/2807/2808/2809/2810/2811/2812/2813/2814/2815/2816/2817/2818/2819/2820/2821/2822/2823/2824/2825/2826/2827/2828/2829/2830/2831/2832/2833/2834/2835/2836/2837/2838/2839/2840/2841/2842/2843/2844/2845/2846/2847/2848/2849/2850/2851/2852/2853/2854/2855/2856/2857/2858/2859/2860/2861/2862/2863/2864/2865/2866/2867/2868/2869/2870/2871/2872/2873/2874/2875/2876/2877/2878/2879/2880/2881/2882/2883/2884/2885/2886/2887/2888/2889/2890/2891/2892/2893/2894/2895/2896/2897/2898/2899/2900/2901/2902/2903/2904/2905/2906/2907/2908/2909/2910/2911/2912/2913/2914/2915/2916/2917/2918/2919/2920/2921/2922/2923/2924/2925/2926/2927/2928/2929/2930/2931/2932/2933/2934/2935/2936/2937/2938/2939/2940/2941/2942/2943/2944/2945/2946/2947/2948/2949/2950/2951/2952/2953/2954/2955/2956/2957/2958/2959/2960/2961/2962/2963/2964/2965/2966/2967/2968/2969/2970/2971/2972/2973/2974/2975/2976/2977/2978/2979/2980/2981/2982/2983/2984/2985/2986/2987/2988/2989/2990/2991/2992/2993/2994/2995/2996/2997/2998/2999/3000/3001/3002/3003/3004/3005/3006/3007/3008/3009/3010/3011/3012/3013/3014/3015/3016/3017/3018/3019/3020/3021/3022/3023/3024/3025/3026/3027/3028/3029/3030/3031/3032/3033/3034/3035/3036/3037/3038/3039/3040/3041/3042/3043/3044/3045/3046/3047/3048/3049/3050/3051/3052/3053/3054/3055/3056/3057/3058/3059/3060/3061/3062/3063/3064/3065/3066/3067/3068/3069/3070/3071/3072/3073/3074/3075/3076/3077/3078/3079/3080/3081/3082/3083/3084/3085/3086/3087/3088/3089/3090/3091/3092/3093/3094/3095/3096/3097/3098/3099/3100/3101/3102/3103/3104/3105/3106/3107/3108/3109/3110/3111/3112/3113/3114/3115/3116/3117/3118/3119/3120/3121/3122/3123/3124/3125/3126/3127/3128/3129/3130/3131/3132/3133/3134/3135/3136/3137/3138/3139/3140/3141/3142/3143/3144/3145/3146/3147/3148/3149/3150/3151/3152/3153/3154/3155/3156/3157/3158/3159/3160/3161/3162/3163/3164/3165/3166/3167/3168/3169/3170/3171/3172/3173/3174/3175/3176/3177/3178/3179/3180/3181/3182/3183/3184/3185/3186/3187/3188/3189/3190/3191/3192/3193/3194/3195/3196/3197/3198/3199/3200/3201/3202/3203/3204/3205/3206/3207/3208/3209/3210/3211/3212/3213/3214/3215/3216/3217/3218/3219/3220/3221/3222/3223/3224/3225/3226/3227/3228/3229/3230/3231/3232/3233/3234/3235/3236/3237/3238/3239/3240/3241/3242/3243/3244/3245/3246/3247/3248/3249/3250/3251/3252/3253/3254/3255/3256/3257/3258/3259/3260/3261/3262/3263/3264/3265/3266/3267/3268/3269/3270/3271/3272/3273/3274/3275/3276/3277/3278/3279/3280/3281/3282/3283/3284/3285/3286/3287/3288/3289/3290/3291/3292/3293/3294/3295/3296/3297/3298/3299/3300/3301/3302/3303/3304/3305/3306/3307/3308/3309/3310/3311/3312/3313/3314/3315/3316/3317/3318/3319/3320/3321/3322/3323/3324/3325/3326/3327/3328/3329/3330/3331/3332/3333/3334/3335/3336/3337/3338/3339/3340/3341/3342/3343/3344/3345/3346/3347/3348/3349/3350/3351/3352/3353~~

the usual confounding of these variables. This was done by maintaining and testing Ss on an a-periodic schedule so as to break up existing temporally conditioned consummatory habits and to prevent the formation of new ones. In the first experiment Ss were tested in the most familiar of situations, viz., their own homecages, where their consummatory habits are already presumably of maximum strength.

#### Method

Subjects.--Ninety-six naive Sprague-Dawley male rats, approximately 75 days old, were used.

Apparatus.--All testing was done in the homecage where S was individually housed. The cages (Wahmann LC-75A) were changed by replacing the front wall by 1/4 in. Plexiglas, drilled to hold a water bottle by its drinking tube. The main lights were kept on a natural 6:00 to 6:00 light-dark cycle. During the dark part of the cycle illumination was provided by a pair of 25-w. red light bulbs. Temperature was kept between 70° and 76° F.

Procedure.--Each S was tested under 12 consecutive deprivation intervals of 7, 14, 21, 28, 35, and 42 hrs., presented twice each in a randomized order. Twenty-four such randomized orders were used and Ss were randomly assigned to subgroups of 4 for each order. Because deprivation times were all multiples of 7 hrs., the times of testing for each animal were evenly scattered around the clock, and successive tests never came 24 hrs. apart. Thus E generally had some testing to do every 7 hrs. for 12 days, but each test session might involve only 4 or 8 Ss. The experiment was run in 4 replications with 24 Ss in each, the first and third with hunger conditions and the second and fourth with thirst conditions. For the eating tests, S's cage was pulled out about 1 in. and 2 or 3 pieces of Wayne Lab Blox, more than S ever ate, were dropped into one corner of the cage. S was allowed 1 hr. to eat. Water was always available. For the drinking test, a drinking tube was presented through the hole in the front of the cage, and S was allowed 30 min. to drink. Food was always available. In the third and fourth replications latencies were measured, by stop watch, from the dropping of the food or the presenting of the drinking tube to the beginning of consummatory behavior. Quantities of food and water were weighed to .5 gm. before and after each test period; spillage was collected and weighed also. Ss were weighed before the first, after the sixth, and again after the twelfth test period. All intake measurements were converted to percentages of S's body weight as measured after the sixth test, i.e., halfway through the sequence.

### Results

After 6 deprivations and tests the hungry Ss had lost a median of 16% and the thirsty Ss 4% relative to their initial ad lib. body weights. After the last test the hungry Ss were down to 21% loss and the thirsty Ss had come up to 1% gain. The upper three graphs in Fig. 1. indicate the mean amount consumed, expressed as a percentage of body weight, for hungry and thirsty Ss as a function of time of day, deprivation time, and test experience.

---

Fig. 1 about here

---

The standard errors of the mean for these data points are generally about .20 percentage points. Thus, several of the effects indicated in Fig. 1 are statistically significant, namely, the time of day effect on water intake, the deprivation effect on both food and water intake, and the learning effect on both food and water intake. More specifically, both hungry and thirsty Ss consumed significantly less at 7 hrs. deprivation than at each of the other deprivation times. In the case of thirsty Ss, intake at both 14 hrs. and 21 hrs. was significantly less than at all of the longer deprivation times.

The bottom part of Fig. 1 gives the latencies to eat or drink of those Ss for which latency was measured. Note that latency scores are presented on a logarithmic scale; this transformation generally normalizes such latency and makes the data variances homogeneous (Bolles, 1962). The latencies to eat were unmeasurably long because values over 120 sec. were designated 120 sec. Consequently, medians are presented in Fig. 1. On the other hand, the latency to drink scores were frequently unmeasurably short. All such short values were designated 1 sec. and the means of these slightly distorted distributions are indicated. Both eating and drinking latencies show a systematic effect only in the case of the experience variable; continued testing leads to continued shortening of latencies.

### Discussion

There is a striking difference between the amount of food consumed by hungry Ss and the amount of water consumed by thirsty Ss. Smaller intake of food cannot be cited

as evidence against the importance of stomach distention in food satiation, however, because, as Lepkovsky, Lyman, Fleming, Nagumo, and Dimmick (1957) have shown, a volume of dry food in the stomach is quickly matched by a like volume of water which is either drunk or transported there from some other sources of water in the body. Thus, the food and water intake curves probably represent approximately equivalent amounts of bulk in the stomach.

Another surprising difference between eating and drinking is the difference in latencies; this difference is even more pronounced than indicated in Fig. 1 because the upper curve represents medians whereas the lower curve represents means. This difference, a factor in the order of 20, may be partly a reflection of the fact that water is always presented in a fixed location whereas the animal has to find food which has been dropped somewhere on the floor. Another factor, however, is the fact that the hungry S typically picks up the food and carries it around for several seconds, and may even go back to pick up a second or third piece of food before beginning to eat, and all this competing preparatory behavior adds to the latency score.

The most interesting difference between food and water intake is their differential dependence upon deprivation time. In the case of eating the function is quite flat; for all deprivations of 14 hrs. or more there is little or no systematic variation, as if the rat eats as much as it can for all deprivations greater than a certain minimum. In contrast with this pattern, water consumption in the thirsty rat increases continuously with increased deprivation time, although it is clear that in this case too the consumption curve must drop sharply at some deprivation time shorter than 7 hrs., and that relative to this sharp change, the part of the function which is shown here will be relatively flat. The implication from this and from the pattern of other results is that different satiation mechanisms are involved in the termination of eating and drinking.

It should be kept in mind that the rat can repair the size of water deficit encountered under the present conditions rather completely even when water is available only 30 min., so that with successive deprivations thirsty Ss do not suffer an appreciable cumulative water deficit. On the other hand, the continued drop in weight and the much greater absolute loss in weight of the hungry Ss indicate that there are cumulative effects of the successive food deprivations. As a consequence, part of the learning to eat

effect shown in Fig. 1 should probably be attributed to a gain in motivation, even though there was no systematic increase in hours deprivation (cf. Eisman, 1956). By the same token, the flatness of the curve for eating as a function of deprivation may reflect the fact that under a given deprivation condition S bases its food consumption not so much on the immediately preceding deprivation, the test deprivation, as on the much larger overall deficit in body weight. What this means, in effect, is that while the present experimental procedure minimizes the confounding ordinarily found between deprivation time and other parameters affecting consummatory behavior, we have not gained much of functional significance because hours deprivation is not a particularly profitable variable to isolate, at least not in comparison with the hungry animal's weight loss.

### Experiment 2

The purpose of the second experiment was to investigate similar relationships in a somewhat different situation, one in which an instrumental response, bar pressing, intervenes between the momentary motivation conditions and S's consummatory behavior.

### Method

Subjects.--The Ss were 39 naive male albino rats, ranging from 75 to 120 days old.

Apparatus.--Two identical Skinner boxes (Foringer 1102-M) were used to run two Ss at a time. Each box was equipped with a Foringer retractable bar that was controlled automatically by a clock so that it could be extended for a consumption test, and then withdrawn. The Foringer bar extends rapidly, making a good deal of noise, so that it provides a good stimulus from which to measure the latency of bar press response in each test. Responses during the tests were recorded cumulatively. The lights in the boxes together with those in the lab were run on a natural 6:00 -6:00 light-dark cycle throughout the experiment. The windows of the Skinner box housings were left open so that other activities in the lab would provide additional diurnal cues. Each bar press delivered a 45 mg. Noyes food pellet, and water was always available. Checking the food and water supplies and general maintenance was done on an irregular number of hours after each S's last meal.

Procedure.--The naive S was deprived 48 hrs., put in the box, and manually shaped up to press the bar for food. S was allowed about 2 hrs. on the training session to eat to satiation. S was then confined to the box for the duration of the experiment, and test sessions (bar presentations) introduced at time intervals that varied randomly from 3 hrs. to 47 hrs. with a mean of 24 hrs. The random schedule of test times was limited only by the restrictions that no feeding session occur at a deprivation time between 21 hrs. and 27 hrs. (excepted as noted below) and that no deprivation times were permitted to fall within 3 hrs. of a previous deprivation time for a given animal. Ss were given from 8 to 13 test sessions, with a median of 11, the exact number being determined by the fact that each S was stopped when its random schedule of tests had yielded approximately uniform distributions across times of day and deprivation times.

The study was run in two replications. In the first replication Ss were given 60 min. tests, and, as noted above, care was taken not to include any deprivation times approaching 24 hrs. After 21 Ss had been run under these conditions and their data had been analyzed it became apparent that information at 24 hrs. was needed and also that 60 min. tests might be too short to obtain satiation under high deprivation. Consequently 18 more Ss were run in a second replication with 90 min. test sessions and with a 24 hr. deprivation time condition. To minimize the possibility of temporal conditioning of the eating habit to a fixed time of testing, however, the 24 hr. test interval was always introduced as the last test condition. Other procedures were the same as before.

### Results

The cumulative records of consummatory performance were analyzed to determine the rate of eating, i.e., the rate of bar pressing, during the first 10 min. of responding. This measure proved to be quite independent of all the parameters controlling eating except deprivation time. The initial rate of responding under 4 hrs. deprivation was 3.2 sec. as against an overall mean rate of 5.2; this difference was significant ( $t = 2.46$ ;  $df = 38$ ;  $p < .01$ ). But there were no other significant departures from the mean rate of responding, nor was there any trend as a function of deprivation time. The cumulative records were

also analyzed to determine whether the amount of time spent eating continuously before stopping for 1 min. or more was related to any of the experimental variables; it was not.

---

Fig. 2 about here

---

The top part of Fig. 2 gives the amount of food consumed, as indicated by the number of bar presses, transformed into percentages of S's initial body weight. It is apparent from the figure that neither time of day nor experience in the test situation has an appreciable effect on intake. There is a non-significant but suggestive indication that S eats more during the dark part of the cycle than during the light part. But this effect is small at best in the present situation. On the other hand, the amount consumed does appear to be a more clear cut function of deprivation time than was the case in Experiment 1. The drop in intake with greater deprivation times is significant ( $t = 2.22$ ;  $df = 17$ ;  $p < .05$ ).

Latency scores for responding to the bar after it is presented provide data on a response which is an additional step removed from the consummatory response, further removed than bar pressing itself. The acquisition of this member of the total consummatory chain is demonstrated by the bottom part of Fig. 2. There were no apparent differences in latency scores between replications, so the results for all Ss have been pooled. Although there was quite rapid learning of this member of the chain, comparable to that obtained in the first experiment for the acquisition of the consummatory habit itself, the apparent asymptote is a relatively slow value of about 15 sec. Again, no significant time of day effect was found. The latency of responding however was shown to be a function of the number of hours deprivation. At 4 hrs. deprivation and at 28 hrs. deprivation Ss responded significantly slower ( $p < .05$ ) than on the average, and at 24 hrs. deprivation they responded significantly faster. Note that this fast latency, and the greater intake, of 24 hr. deprived hungry Ss cannot be attributed just to the fact that the 24 hr. test condition was the last test given, because as the other part of the figure shows, there was no appreciable learning effect after the first 4 consummatory tests.



## Discussion

The replication with 90 min. tests was run because the flatness of the consumption vs. deprivation time curve obtained with 60 min. tests suggested that S might not be getting sufficient time to eat to satiation. This possibility was then supported by the finding that under high deprivation (greater than 24 hrs.) SS ate about 15% of their total meal between the 60th and 90th minutes, whereas under low deprivation (less than 24 hrs.) the meal was nearly always finished by 60 min. On the other hand, the rate measures and the measures of the amount consumed in 60 min. showed that under high deprivation SS ate somewhat more slowly in the 90 min. tests than in the 60 min. tests. Moreover, the overall median size was only 4% larger with the longer test sessions. Hence the flatness of the consumption curves cannot be reasonably attributed to the test time limitation.

The recent results of Dufort & Wright (1962) are particularly interesting in this connection because their SS were tested just once, at the same time of day, and they were deprivationally naive at the time of testing. Thus in Dufort and Wright's results there is relatively little confounding between the motivational effects of deprivation and the associative effects introduced by the test conditions. They found, as was found here, that the amount eaten was maximal with deprivation times of approximately 30 hrs.

The sharp rise in consumption between 0 and 4 hrs. deprivation time has also been observed in consummatory behavior (Horenstein, 1951) and in other instrumental situations (Saltzman & Koch, 1948; Horenstein, 1951; Kimble, 1951). This discontinuity in the function suggests that consummatory behavior is under the control of two separate mechanisms. There is one, which perhaps involves stomach distention, that determines whether the animal will eat at all, and a second, involving weight loss, which comes into play somewhere before 4 hrs. deprivation, that determines how much food S will take to reach satiation. It would appear that the rat is constituted so that if it is willing to eat at all, it will eat nearly a full-sized meal. This conclusion is supported by the results of other studies using long test times (Bousfield & Elliott, 1934; Lawrence & Mason, 1955a; Dufort & Wright, 1962).

Smith and Duffy (1957), and Smith, Pool and Weinberg (1962), and others have demonstrated that the bulk of the stomach contents, or the distention of the stomach, is one factor controlling the amount of food a rat will consume. Such an effect can undoubtedly account for S's failure under relatively short deprivations (those less than 24 hrs.) to make its food intake proportional to its caloric deficit, but some additional mechanism seems to be necessary to account for the decline in consumption with deprivations longer than 30 hrs.

One of the surprising features of the results in the Skinner box situation is the failure of consumption to increase with successive meals (Figure 2). Such a finding is in sharp contrast with the gradual acquisition of eating obtained by Ghent (1951, 1957). The difference may be due in part to the fact that, because of the 48 hr. deprivation prior to training, the present Ss entered the test situation with considerable weight loss (between 12 and 15%), and not much more weight was lost during testing, whereas under the conditions Ghent used, her Ss undoubtedly continued to lose weight throughout the course of testing. Another possible factor is that the consummatory habit may receive much more effective reinforcement per meal in the Skinner box situation than it does when food is presented in an open dish. Dividing the meal into a large number of discrete 45 mg. pellets may provide a large number of reinforcements for the eating habit so that the consummatory response had been brought essentially to full strength in the Skinner box situation during the initial training session, i.e., prior to the beginning of testing. If this is the case, then this procedure can tell us little about the acquisition of the consummatory habit itself.

It may be noted that the pattern of latency of responding to the bar presentation as a function of hours deprivation (Fig. 2, bottom) suggests that time of day cues have much more control over this instrumental member of the response chain than they do over the consummatory response itself (Experiment 1). It is as if the animal becomes "vigilant" about 24 hrs. after the last meal, but that vigilance fails as further time elapses. The fact that such a 24 hr. effect could be shown under a-periodic maintenance conditions implies that some temporal conditioning of the response can be demonstrated after a single reinforcement (cf. Bolles & de Lorge, 1962).

Food intake in the Skinner box shows a more pronounced dependence upon deprivation time than it does in the homecage. This difference may be an artifact reflecting differences in the size, composition or palatability of the foods, or it may indicate something about the difference between consummatory and instrumental behavior. Perhaps the simplest explanation, however, is that more weight was lost by Ss in the homecage experiment, and that the differences in Weight produced by the immediately preceding deprivation were of less relative importance than Ss' continuing, and growing, overall weight loss.

In conclusion, deprivation time in hours since last eating seems to reveal little about S's hunger motivation; it is only weakly related to the strength of instrumental behavior, and still less clearly demonstrated in the strength of consummatory behavior. At least, this seems to be the case when S has an appreciable body weight loss. Under these conditions body weight loss itself is strongly implicated as the principal determinant of S's hunger motivation.

# References

- Bare, J. K. Hunger, deprivation, and the day-night cycle. J. comp. physiol. Psychol., 1959, 52, 129-131.
- Bolles, R. C. The readiness to eat and drink: the effect of deprivation conditions. J. comp. physiol. Psychol., 1962, 55, 230-234.
- Bolles, R. C., & de Lorge, J. The rat's adjustment to a-diurnal feeding cycles. J. comp. physiol. Psychol., 1962, 55, 760-762.
- Bousfield, W. A., & Elliott, M. H. The effect of fasting on the eating behavior of rats. J. genet. Psychol., 1934, 45, 227-237.
- Dufort, R. H., & Wright, J. H. Food intake as a function of duration of food deprivation. J. Psychol., 1962, 53, 465-468.
- Eisman, E. An investigation of the parameters defining drive (D). J. exp. Psychol., 1956, 52, 85-89.
- Ghent, L. The relation of experience to the development of eating. Canad. J. Psychol., 1951, 5, 77-81.
- Ghent, L. Some effects of deprivation on eating and drinking behavior. J. comp. physiol. Psychol., 1957, 50, 172-176.
- Horenstein, B. R. Performance of conditioned responses as a function of hunger drive. J. comp. physiol. Psychol., 1951, 44, 210-224.
- Kessen, W., Kimble, G. A., & Hillman, B. M. Effects of deprivation and scheduling on water intake in the white rat. Science, 1960, 131, 1735-1736.
- Kimble, G. A. Behavior strength as a function of the intensity of the hunger drive. J. exp. Psychol., 1951, 41, 341-348.
- Lawrence, D. H., & Mason, W. A. Food intake in the rat as a function of deprivation intervals and feeding rhythms. J. comp. physiol. Psychol., 1955, 48, 267-271. (a)
- Lawrence, D. H., & Mason, W. A. Intake and weight adjustment in rats to changes in feeding schedule. J. comp. physiol. Psychol., 1955, 48, 43-46. (b)
- Lepkovsky, S., Lyman, R., Fleming, D., Nagumo, M. & Dimmick, M. M. Gastrointestinal regulation of water and its effect on food intake and rate of digestion. Amer. J. Physiol., 1957, 188, 327-331.
- Mandler, J. M. Irregular maintenance schedules and drives. Science, 1957, 126, 505-507.
- Miller, N. E. Shortcomings of food consumption as a measure of hunger: results from other behavioral techniques. Ann. N. Y. Acad. Sci., 1955, 63, 141-143.
- Miller, N. E. Effects of drugs on motivation: the value of using a variety of measures. Ann. N. Y. Acad. Sci., 1956, 65, 1271-1278.

- Saltzman, L., & Koch, S. The effect of low intensities of hunger on the behavior mediated by a habit of maximum strength. J. exp. Psychol., 1948, 38, 347-370.
- Smith, M., & Duffy, M. Some physiological factors that regulate eating behavior. J. comp. physiol. Psychol., 1957, 50, 601-608.
- Smith, M., Pool, R., & Weinberg, H. The role of bulk in the control of eating. J. comp. physiol. Psychol., 1962, 55, 115-120.
- Stellar, E., & Hill, J. H. The rat's rate of drinking as a function of water deprivation. J. comp. physiol. Psychol., 1952, 45, 96-102.

Footnote

1. The first experiment was supported by research grant N<sub>s</sub>G-396 from the National Aeronautics and Space Administration. Marianne Yost collaborated on the study. The second experiment was supported by research grant G-10731 from the National Science Foundation. John de Lorge assisted in the data collection.

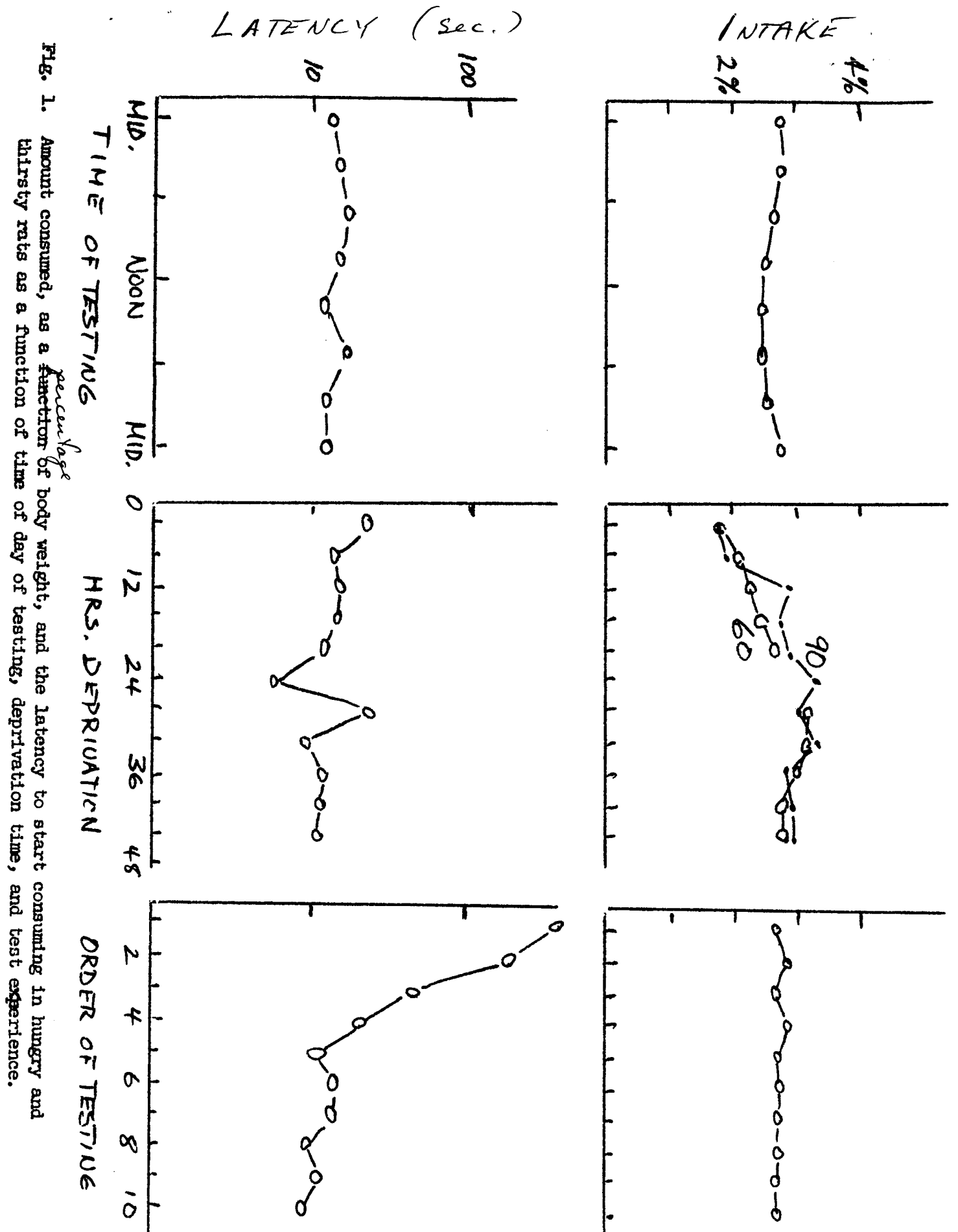


Fig. 1. Amount consumed, as a function of body weight, and the latency to start consuming in hungry and thirsty rats as a function of time of day of testing, deprivation time, and test experience.

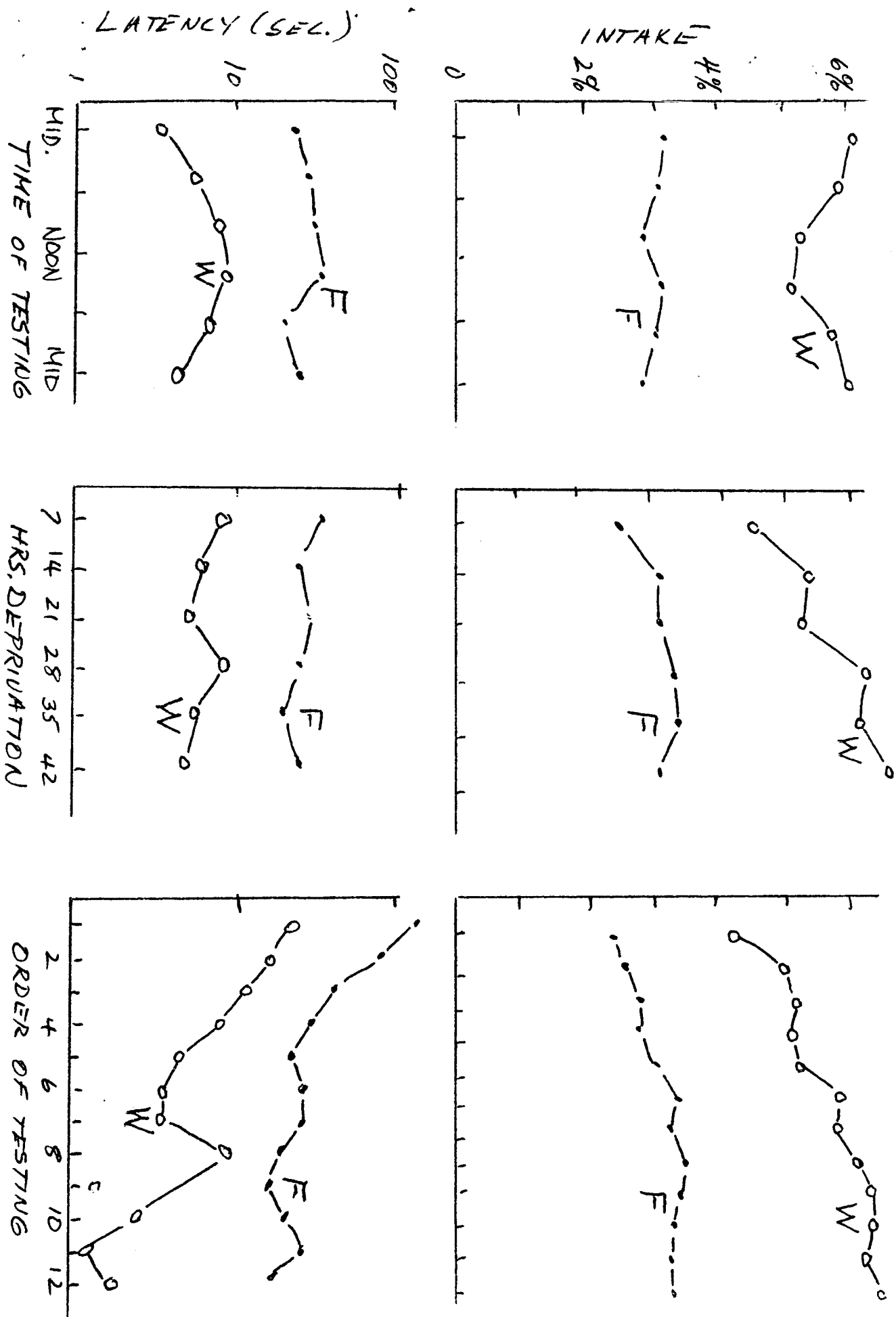


Fig. 2. Amount consumed, as a percentage of body weight, and latency to start responding to food as a function of time of testing, deprivation time, and test experience.